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(54) Equipment for producing an nmr image as a planar projection

(57) In a system for imaging a subject 2 by means of nuclear magnetic resonance, and including means 3 for the application of magnetic fields to the subject and for detecting excursions of atomic nuclei of the subject from their state of equilibrium by a high-frequency magnetic excitation pulse, means 13, 17 control the image production so that the image produced represents a projection of at least part of the subject on to a prescribed plane 1. In this way complete pictures, corresponding to X-ray shadow images, are produced with the aid of nuclear magnetic resonance. As described, a magnetic field gradient defines a slice of the subject for projection, successive slices being selected by moving the subject or varying the frequency of the excitation pulse to build up the projection a line at a time.

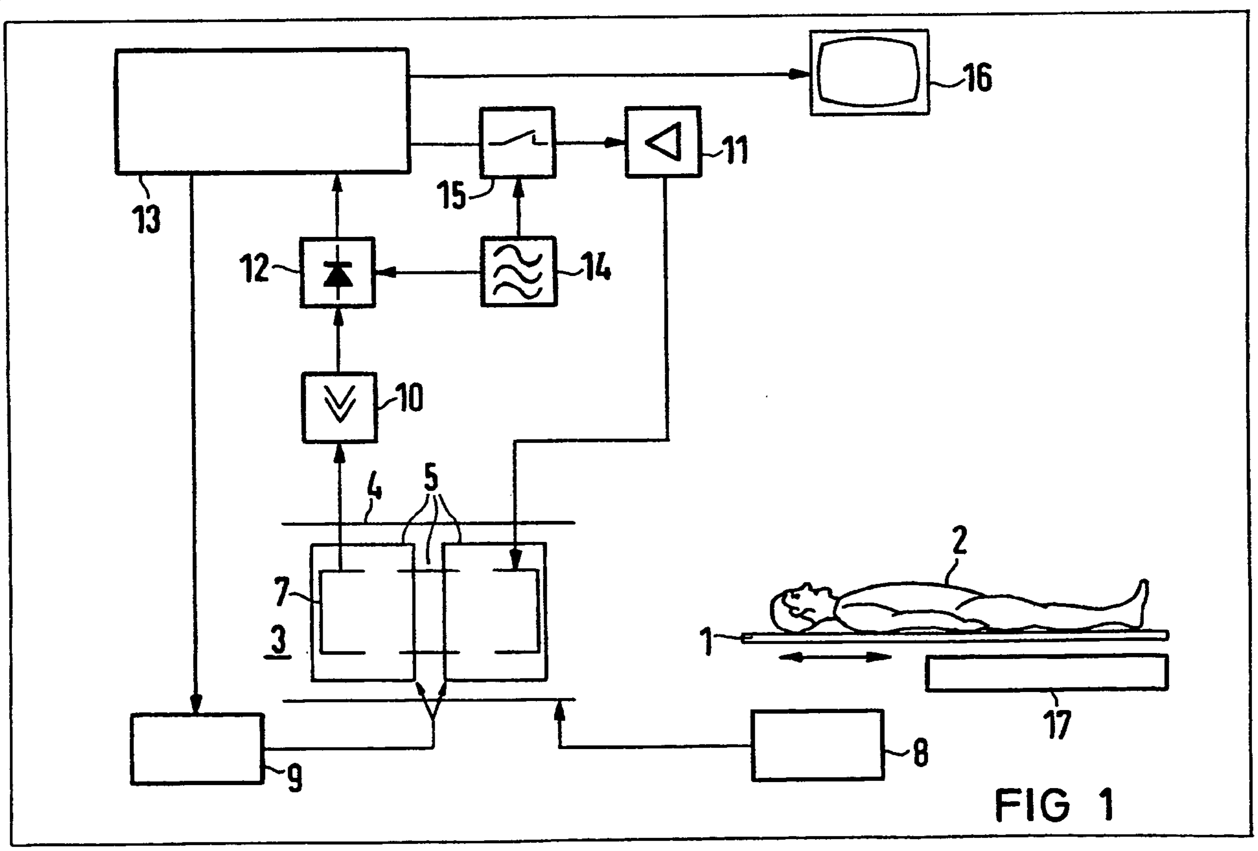

FIG 1

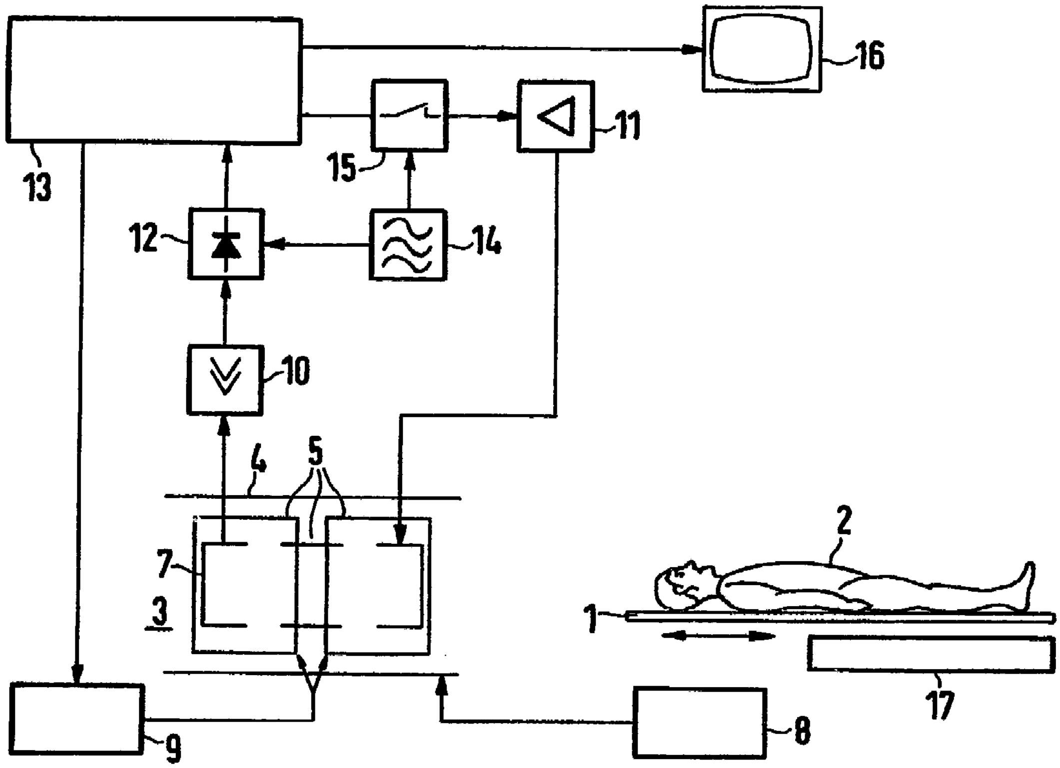

FIG 1

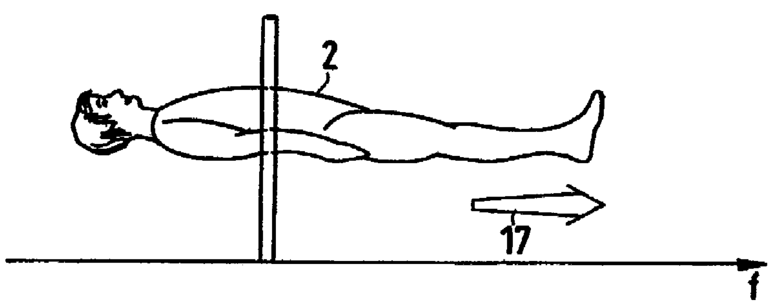

FIG 2

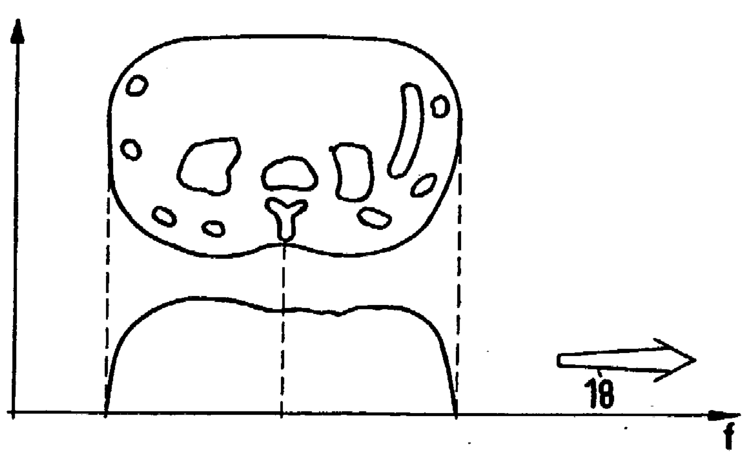

FIG 3

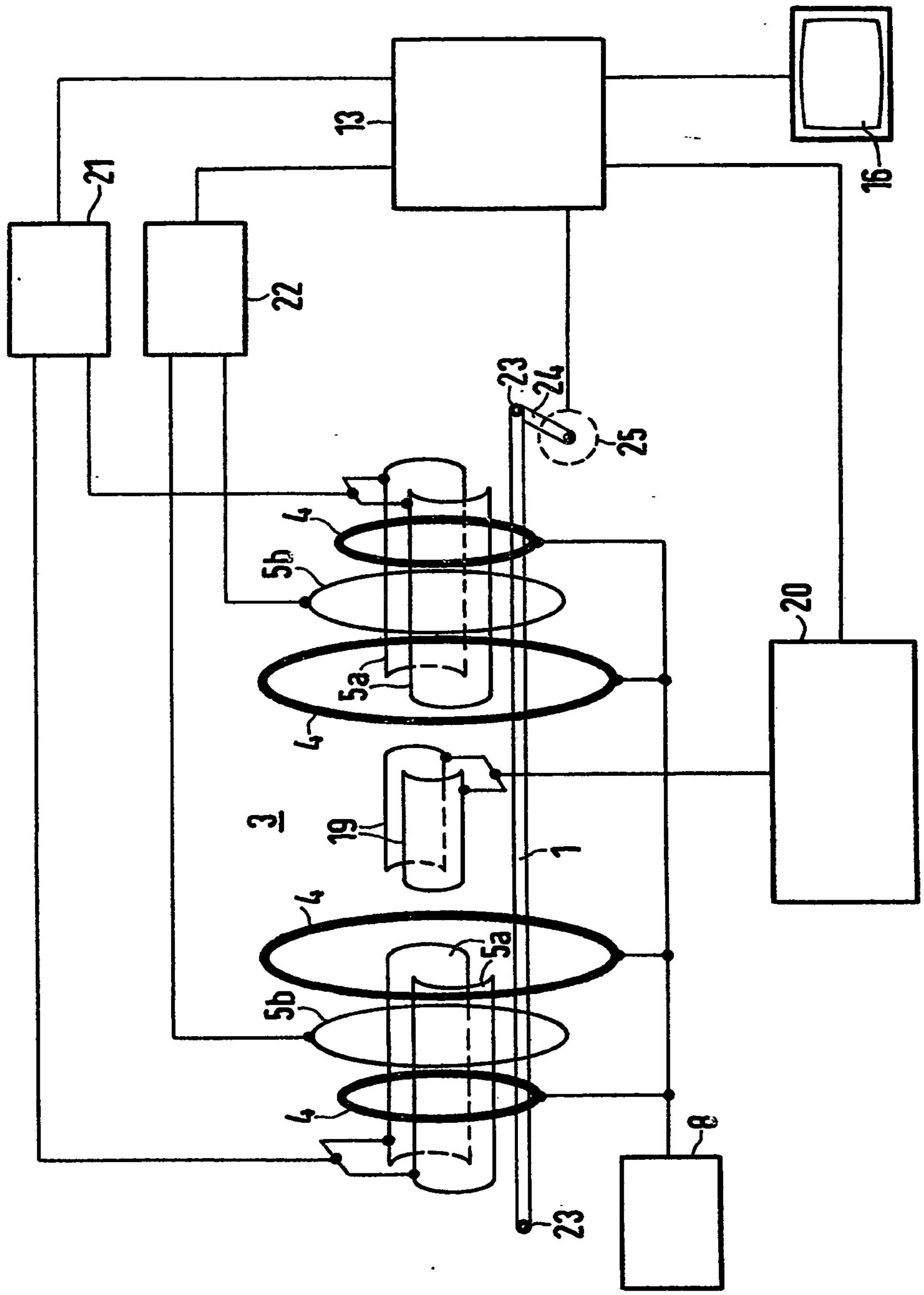

FIG 4

SPECIFICATION

Equipment for producing an image of at least part of an examination subject

The present invention relates to equipment for producing an image of at least part of an examination subject by means of nuclear magnetic resonance. More particularly, the present invention relates to such equipment in which there are means for the application of magnetic fields on to the examination subject and for detecting the excursions of atomic nuclei of the examination subject from their state of equilibrium of a high-frequency magnetic excitation pulse.

It is known that hydrogen atomic nuclei, in particular, of an examination subject can be deflected from a preferred direction, which is produced by magnetic base field, by a high-frequency excitation pulse and that, when the excitation pulse ceases, there is a certain delay before the atomic nuclei level off into the preferred direction, as a result of their spin. During this delay, the atomic nuclei precess with a frequency determined by the strength of the magnetic base field. If a field gradient is superimposed on this uniform magnetic base field so that the magnetic field distribution is varied spatially, it is possible to take a bearing by means of the frequency measured in each case. It is also known that it is possible to produce images of layers through the examination subject in this way and by changing the direction of the field gradient. Excitation in one layer of the examination subject is produced in this connection by influencing the magnetic base field by means of a further field gradient so that atomic nuclei are activated in this layer only. This is possible because the excitation is produced with only one frequency, which is associated strictly with the magnetic field in the required layer.

According to the present invention, there is provided equipment for producing an image of at least part of examination subject by means of nuclear magnetic resonance, in which equipment there are means for the application of magnetic fields on to the examination subject and for detecting excursions of atomic nuclei of the examination subject from their state of equilibrium by a high-frequency magnetic excitation pulse, and control means for controlling the image production such that the image produced represents a projection of at least part of the examination subject to be depicted or of parts of the examination subject on to a prescribed plane.

Equipment according to the invention produces a projection not, as in the prior art, which is representation of a selected layer of the examination subject, but instead an image produced which corresponds, for example, to an X-ray shadow image.

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a representation of an example of equipment according to the invention;

Figures 2 and 3 are representations to illustrate the operation of the equipment; and

Figure 4 shows details of the equipment according to Figure 1.

Figure 1 shows a patient 2, images of whom are to be produced with the aid of nuclear magnetic resonance, lying on a couch 1. In this connection, there is a coil system 3 having a coil 4 for producing a uniform magnetic field, gradient coils 5 for varying this magnetic field, and an excitation and measuring coil 7. The coil 4 is connected to a power supply 9, and the excitation and measuring coil 7 are connected to a pre-amplifier 10 and, by means of suitable coupling elements, to a transmitter amplifier 11. The pre-amplifier 10 supplies a measurement signal via a phase-selective rectifier 12 to a process computer 13 which controls the entire measuring procedure. A high frequency oscillator 14, which may be connected, as shown, via a modulator 15 to the transmitter amplifier 11, is used to produce excitation pulses. the images produced are reproduced on a monitor 16.

To produce an image of the patient 2 with the aid of nuclear magnetic resonance, the couch 1 is introduced with the aid of a control device 17, which is also controlled by the process computer 13, into the coil system 3 so that a first transverse layer through the patient 2, in whose head several layers are to be imaged, is located such that, as a result of the magnetic field there, nuclear magnetic resonance is excited by an excitation pulse in the coil 7. Data is accumulated from the measurement signal picked up with the aid of the coil 7, which data embodies information relating to a one-dimensional projection of the excited layer through the patient 2 on to a prescribed plane of projection. After this data has been gathered, the couch 1 is displaced longitudinally so that an adjacent, parallel layer through the patient 2 is now positioned at a point at which it can be excited by an excitation pulse of the coil 7. Data is now accumulated which embodies information relating a one-dimensional projection of this excited layer on to the plane of projection. Another longitudinal movement is then effected to excite a further parallel layer and data corresponding to this is accumulated, and so on. There may thus be produced images of a plurality of parallel layers through the patient 2 by means of longitudinally moving the patient 2 on the couch 1, nuclear magnetic resonance being excited in one layer only at a time

The image producing process is completed after all the required parallel layers corresponding to the area to be represented have been excited in this way, and after the processing of the data thereby produced corresponding to the region of the patient 2 to be represented, a projection of which is to be made on to a prescribed plane, more particularly on to the couch 1. An image representing the projection has now been produced.

Instead of the described step-wise longitudinal displacement of the couch 1 with the patient 2, it is also possible to produce the desired images by a

step-wise variation of the frequency of the excitation pulse supplied to the coil 7. If the remaining coils have a constant field, the layer in which the atomic nuclei are deflected from their state of equilibrium is caused to move through the patient 2 because the layer in which the excitation takes place in each case depends on the magnetic field and on the frequency of the excitation pulse. Therefore, in this way it is possible, without moving the patient, to produce data which embodies information relating to a one-dimensional projection of the layer excited in each case on to the plane of projection, each of a plurality of parallel layers through the patient 2 being excited, one at a time. The frequency of the excitation pulse can be altered by varying the low frequency supplying the modulator 15.

It is also possible to design the equipment so that two-dimensional images of the subject to be depicted can be produced in a known manner and it is therefore possible not to define the layers of which these images are produced. In this case the images represent a parallel projection of the patient 2 on to a prescribed plane. It is also conceivable to project parts only of the patient 2 in this way and to put together several part images to form a larger projection image.

Figure 2 shows that the layer through the patient 2 which is excited is determined by the local variation of the flux intensity and thus the nuclear resonance frequency. The field gradient is represented diagrammatically in Figure 2 and designated by 17. The resonance frequency is designated by *f*. In this connection the atomic nuclei are excited only in the region of the patient 2 which has been represented.

Figure 3 shows a cross-section through the excited region of the patient 2 and, below that, the pattern of the signal amplitude of the signal measured after the excitation, as a function of the nuclear resonance frequency. As a result of the diagrammatically represented field gradient 18 used in this Figure, the signal amplitude is dependent on the nuclear resonance frequency such that a pattern is produced representing a projection of the examined layer of the patient 2 into the direction of the field gradient 18. An overall image can now be reconstructed, as described, from several projections of this kind.

Figure 4 represents in more detail one possible construction of the coil system 3. In particular, Figure 4 shows that the coil 4 is divided into four to produce a uniform magnetic field (base field). It is supplied by the power supply 8. The gradient coils, designated by 5 in Figure 1, are subdivided in the example represented in Figure 4 into two pairs of gradient coils 5*a* to produce a field gradient in the x-direction, i.e. transverse the couch 1, and into a pair of gradient coils 5*b* to produce a field gradient in the longitudinal direction of the couch 1 (the z-direction). In the embodiment according to Figure 4, a pair of coils 19 connected to a combined high frequency transmitter and receiver system 20 is used to excite atomic nuclei and for the measurement. The process computer 13 supplies a drive 21 for the pairs of gradient coils 5*a* and a drive 22 for the pair of gradient coils 5*b*. According to Figure 1 it effects the reproduction of the calculated image on the monitor 16.

In the example in Figure 4, the couch 1 for the patient 2 consists of a transporting belt passed over rollers 23 and driven in a step-wise manner by a gear mechanism 24 of a stepping motor 25. The stepping motor 25 is controlled by the process computer 13 so that it moves the patient 2 in steps through the coil system 3.

In order to produce two-dimensional images of the subject when the layer is not limited, a y-gradient coil system, which corresponds entirely to the gradient coil system 5*a* rotated by 90° about the magnetic axis, may be provided in addition to the gradient coils represented in Figure 4.

CLAIMS

1. Equipment for producing an image of at least part of examination subject by means of nuclear magnetic resonance, in which equipment there are means for the application of magnetic fields on to the examination subject and for detecting excursions of atomic nuclei of the examination subject from their state of equilibrium by a high-frequency magnetic excitation pulse, and control means for controlling the image production such that the image produced represents a projection of at least part of the examination subject to be depicted or of parts of the examination subject on to a prescribed plane.

2. Equipment according to claim 1 wherein, for the line-by-line formation of the projection, the said means for the application of magnetic fields comprises coils for the selective excitation of nuclear magnetic resonance in a layer perpendicular to the projection direction, from which data is produced which embodies information relating to a one-dimensional projection of the excited layer on to the plane of projection, and wherein a plurality of parallel layers in the examination subject may be excited one at a time by means of the control means.

3. Equipment according to claim 2, wherein, for the excitation of a plurality of parallel layers through the subject, there is a longitudinally displaceable couch for the subject, by means of which the subject may be moved through the coil system.

4. Equipment according to claim 2, wherein the frequency of the excitation pulse can be altered for the excitation of a plurality of parallel layers through the subject.

5. Equipment according to any preceding claim, wherein means is provided for producing two-dimensional images of the subject and there is no definition of the layer, of which the images are produced, in the direction of the layer thickness.

6. Equipment for producing an image of at least

part of an examination subject by means of nuclear magnetic resonance, substantially as herein described with reference to Figure 1 or Figures 1 and 4 of the accompanying drawings.

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